VIBRATION ATTENUATED POWER TOOL

The present invention relates to power tools and relates particularly, but not exclusively, to percussive power drills.

Power drills for drilling masonry are known in which a percussive action is imparted to the drill bit by means of cooperating ratchet plates on a shaft supporting the drill bit and a body of the drill relative to which the shaft rotates. As the cooperating ratchet plates rotate relative to each other, the ratchet plate on the shaft supporting the drill bit is provided with an axial impulse, which is transmitted to the drill bit.

Percussive drills of this type suffer from the drawback that the interaction of a drill bit of such a drill with masonry being drilled generates significant vibrations, which can be detrimental to the health of users of the drill over prolonged periods of use. Such vibrations generally include a high frequency component caused by the vibration of the ratchet plates, typically in the region of 580 Hz, and a low frequency component caused by vibration of a drill bit of the drill in a hole being formed by the drill. Of particular concern are the low frequency components of vibration (typically 10 – 20 Hz), which are found to cause the most significant long-term health problems. As a result, standards relating to hand-arm vibration use weighting factors to describe the level of vibration likely to cause injury. In particular, a mathematical filter equation is used which emphasises frequencies closest to the 10 – 20 Hz band, but duration of exposure as well as instantaneous vibration level is taken into account.

It is known to attempt to reduce the vibrations transmitted to the hands of a user of a power tool by providing vibration attenuating material such as an elastomeric material around at least those parts of the tool housing which are held by the user. However, the stiffness of elastomeric materials is generally too high to significantly attenuate the low frequency component of the vibrations generated by operation of the tool, the low frequency component generally being the most damaging to health.

Preferred embodiments of the present invention seek to overcome the above disadvantages of the prior art.

According to the present invention, there is provided a power tool comprising:-

a housing;

a motor within the housing for actuating a working member of the tool, the motor having a stator and a rotor adapted to rotate about a first axis relative to said stator; and

resilient first vibration attenuating means acting between a working member of said tool and said housing for attenuating vibrations along three orthogonal axes transmitted from a working member of said tool to said housing.

By providing resilient first vibration attenuating means for attenuating vibrations transmitted from a working member of the tool to the housing of the tool, this provides the surprising advantage of reducing the level of vibration transmitted to the hands of a user of the tool much more effectively than in the prior art. This is particularly the case for the harmful low frequency components of such vibrations, for example as caused by vibration of a drill bit of the tool in a hole to be drilled, but is also applicable to higher frequency components, for example as generated by rotating ratchet plates of a percussive drill..

Said first vibration attenuating means may comprise a plurality of resilient members.

Said first vibration attenuating means may act between a bearing of said rotor and said housing.

In a preferred embodiment, the tool further comprises a gearbox connected to said motor, and said first vibration attenuating means acts between said gearbox and said housing.

The tool may comprise a plurality of first said resilient members and a plurality of second said resilient members, wherein said first and second resilient members

are circumferentially spaced about said first axis, and said first resilient members are circumferentially offset relative to said second resilient members.

Said first and second resilient members may be arranged substantially perpendicularly to said first axis.

The tool may further comprise at least one third said resilient member arranged substantially parallel to said first axis.

This provides the advantage of enabling the stiffness of the tool along the first axis to be increased to prevent the tool from becoming too compliant in an axial direction.

At least one said resilient member may have adjustable resilience.

This provides the advantage of enabling adjustment of the frequency at which vibrations are most effectively attenuated.

At least one said resilient member may comprise a respective spring acting against a respective abutment having adjustable position.

The tool may further comprise second vibration attenuating means for attenuating vibrations transmitted from said stator to said housing in a direction substantially parallel to said first axis.

By providing second vibration attenuating means for attenuating vibrations transmitted from the stator to the housing, this provides the surprising advantage of much more effectively reducing the level of vibration transmitted to the hands of a user of the tool, and is especially effective in reducing transmission of the high frequency components typically caused by ratchet plates of a percussive power drill. The further advantage is provided that forces can be more effectively transmitted into a workpiece, with the effect that a power drill having ratchet plates to impart a hammer action to a drill bit operates more effectively for a given ratchet plate profile.

In a preferred embodiment, the stator is displaceable relative to said housing in a direction substantially parallel to said first axis, and the second vibration attenuating means comprises biasing means for resisting said displacement of said stator relative to said housing at least in a direction substantially parallel to said first axis.

In a preferred embodiment, the second vibration attenuating means acts between said stator and a support.

Said biasing means may comprise at least one further resilient member.

Said biasing means may comprise a plurality of first said further resilient members circumferentially spaced around said first axis and a plurality of second said further resilient members offset from said first further resilient members in a direction parallel to said first axis.

By providing circumferentially spaced further resilient members, this provides the advantage of allowing axial displacement of said stator relative to the or each said rotor bearing while maintaining torsional rigidity of said motor.

Said first further resilient members may be circumferentially offset relative to said second further resilient members.

At least one said further resilient member may comprise at least one respective leaf spring.

The resilience of at least one said further resilient member may be adjustable.

This provides the advantage of enabling the frequency at which vibrations are most effectively attenuated to be adjusted, which in turn enables the resilience of the second vibration attenuating means to be tuned, for example, to the frequency of operation of ratchet plates of a percussive drill.

In a preferred embodiment, at least one said leaf spring comprises a plurality of removable spring members.

By providing a leaf spring comprising a plurality of removable members, for example in the form of a set of multiple laminations of spring plates, this provides the advantage of enabling the resilience of the second vibration attenuating means to be easily adjusted.

The second vibration attenuating means may comprise a plurality of interchangeable said further resilient members having different resiliencies.

This enables the resilience of the second vibration attenuating means, and therefore the frequency at which vibrations are most effectively attenuated, to be adjusted by replacing one further resilient member with another further member of different resilience.

A preferred embodiment of the invention will now be described, by way of example only and not in any limitative sense, with reference to the accompanying drawings, in which:-

Figure 1 is a perspective schematic view of a power drill embodying the present invention;

Figure 2 is a side elevation view of the power drill of Figure 1;

Figure 3 is a rear view of the power drill of Figure 1;

Figure 4 is a perspective schematic view of a motor and gearbox assembly and first vibration attenuating means of the power drill of Figures 1 to 3;

Figure 5 is a schematic perspective view of the assembly of Figure 4 with the rotor bearing supports and the first vibration attenuating means removed;

Figure 6 is a schematic perspective view of a second vibration attenuating means of the assembly of Figures 4 and 5;

Figure 7 is a graph showing the variation of amplitude of vibration transmitted to a hand of a user with frequency for the drill of Figures 1 to 6; and

Figure 8 is a graph showing variation of force applied to a masonry load with frequency for the drill of Figures 1 to 6.

Referring to Figures 1 and 2, a power drill 2 has a housing 4 incorporating a motor 6 for driving an output shaft 8 via a gearbox 10, in a manner which will be

familiar to persons skilled in the art. The output shaft 8 carries a chuck 12 to which a drill bit (not shown) is mounted, and cooperating ratchet plates (not shown) contained within the gearbox 10 are connected to an output gear of the gearbox 10 and to the output shaft 8 respectively, to impart a percussive action to the chuck 12 as they are rotated relative to each other as a result of rotation of the output shaft 8 relative to the housing 4. Rotation of the output shaft 8 is caused by actuation of the motor 6, which is powered by squeezing a trigger 18 provided on a handle 20. The drill 2 is also provided with a further handle 22.

Referring now to Figures 4 and 5, the motor 6 comprises a stator 24 and a rotor 26, the rotor 26 being mounted to rear 28 and front 30 bearings so that the rotor 26 can rotate about axis 32 relative to stator 24. The rotor 26 also carries a fan 34 for generating air flow to cool the motor 6 in a manner which will be familiar to persons skilled in the art.

The stator 24 is mounted to a support 36 by means of a vibration attenuating means in the form of two sets of three leaf springs 38 spaced equiangularly about the rotation axis 32 of rotor 26 and arranged at opposite axial ends of the stator 24 (only one set of leaf springs 38 being shown in Figures 5 and 6). Each set of leaf springs 38 is clamped to an end of the stator 24 by means of a respective end plate 40, and each leaf spring 38 is formed from multiple removable laminate sections, so that the spring force of each leaf spring 38 can be adjusted by adding or removing laminate sections. The leaf springs 38 at the opposite ends of the stator 24 are offset from each other by approximately 60 degrees. In this way, the stator 24 can move axially relative to support 36, but torsional movement of the stator 24 relative to the support 36 is minimised. In this way, the leaf springs 38 serve to absorb the high frequency component of vibrations, which is generally caused by vibration of the ratchet plates in gearbox 10, and is typically near to 580 Hz.

Referring now to Figure 4, the support 36 is rigidly mounted to rear shaft bearing 28 and to forward shaft bearing 30 by means of screws (not shown). The rear bearing 28 is then mounted to the housing 4 by means of a set of three equiangularly spaced compression springs 42. Each of the springs 42 is located in a spring cup 44, and the spring cups 44 are threaded and located in respective sleeves

46 (Figures 1 and 2) in the housing 4 to allow adjustment of the pre-loading of springs 42, which in turn adjusts the resonant frequency of oscillation of the motor 6 relative to the housing 4.

Similarly, the forward bearing 30 is mounted to the housing 4 by means of three equiangularly arranged compression springs 48, which are offset at approximately 60 degrees relative to compression springs 42, and which in turn are located in respective spring cups 50 which are threaded and located in respective sleeves 52 in housing 4 to allow adjustment of the pre-loading of the springs 48. The springs 42, 48 form a further vibration attenuating means, for minimising the transmission of vibrations from the motor 6 to the housing while avoiding making the drill bit (not shown) too compliant relative to the housing 4. It is found that the springs 42, 48 are particularly effective in attenuating both the low and high frequency components of vibration caused by vibration of the drill bit in a hole being drilled.

Furthermore, although not specifically shown in the embodiment described above, one or more compression springs can be arranged along axis 32 between the rear portion of the motor 6 and the housing 4. This avoids the drill bit becoming too compliant relative to the housing 4 in an axial direction, ensuring that the steady application of force by the user onto a masonry workpiece results in acceptable axial spring displacement.

The operation of the power drill 2 shown in Figures 1 to 6 will now be described with additional reference to Figures 7 and 8.

When the motor 6 is energised by squeezing trigger 18 on handle 20, the output shaft 8 rotates, which in turn rotates chuck 12 and drill bit (not shown) and the ratchet plates located in gearbox 10 impart a percussive action to the drill bit. Transmission to the housing 4 of high frequency vibrations generated as a result of relative rotation of the ratchet plates in gearbox 10 is minimised as a result of the axial movement of motor stator 24 relative to the housing support 30, and of movement of the support 30 relative to the housing 4 about axes generally perpendicular and parallel to the axis 32 of rotation of the motor rotor 26 relative to the stator 24. Also, movement of the support 30 relative to the housing 4 is effective

in attenuating harmful low frequency vibrations caused by vibration of the drill bit in the hole being drilled.

In particular, Figure 7 shows the modulus of hand-arm velocity reduction for the user of the drill, compared with ratchet input velocity, from which it can be seen that by suitably adjusting the spring force of springs 38, 42, 48, the transmission of vibrations to the user's hand is minimised at a ratchet plate frequency of 580 Hz. However, Figure 8 shows the modulus of force applied to a masonry load by the drill 2 of Figures 1 to 6 compared to ratchet input velocity. At the relevant frequency of 580 Hz, it can be seen that the force delivered to the load is increased, while the vibrations transmitted to the user are decreased. It can therefore be seen that the drill 2 enables more effective operation of the drill for a given ratchet plate profile to be achieved, which minimises the effect of vibrations on the user.

The present invention uses the principle of dynamic absorption to minimise the transmission of harmful vibrations to the user. The high frequency vibrations at the ratchet plates act predominantly along the rotation axis 32, as a result of which the high frequency vibrations can be effectively attenuated by allowing limited axial movement of the motor stator 24 relative to the housing. The more harmful low frequency vibrations are caused predominantly by vibration of the drill bit in a hole being drilled in masonry, and produce components of low frequency vibration along all three axes, i.e. both along and perpendicularly to the axis 32. As a result, the low frequency vibrations are attenuated by springs 42, 48, which allow damped movement of the drill bit relative to the housing in all three directions.

It will be appreciated by persons skilled in the art that the above embodiment has been described by way of example only, and not in any limitative sense, and that various alterations and modifications are possible without departure from the scope of the invention as defined by the appended claims. For example, instead of using leaf springs 38 or compression springs 42, 48, solid links or rubber elements could also be used. Also, compression springs 42, 48 may be mounted between gearbox 10 and housing 4 instead of, or in addition to, between rear shaft bearing 28 and housing 4 or between front bearing 30 and housing 4.